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PROGRAM UPDATE - JUNE 2002

Laser Science & Technology

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Phase-Locked, Antiguided Multiple-Core Ribbon Fiber Laser

Under the support of the Laboratory Directed Research & Development Program (LDRD) and U.S. Air Force Research Laboratory (AFRL), Albuquerque, N. M., we are developing a scalable multiple-core ribbon fiber laser to generate short-pulse, high-average-power (kW-scale) coherent light for possible applications in the military, material processing, and x-ray generation.

The development of double-clad fiber has brought fiber lasers to the forefront of possible approaches for high-beam-quality, high-average-power laser sources. Using a cladding-pumped geometry with a single-mode core, individual fibers have been demonstrated to yield greater than 100 W of average power. However, it is difficult to increase the outputs of these single-core fiber lasers to higher levels because of the onset of optical facet damage and deleterious nonlinear optical interactions at high irradiance. Critical to increasing the average power capability of fiber lasers is enlarging the aperture area of the laser radiation emerging from the fiber. One way to increase the aperture available to the laser radiation is to employ multiple cores that are phase-locked to yield a coherent output beam. The conventional power scaling techniques using evanescent coupling have not been very successful because of phase fidelity degradation between distant cores in large-diameter fibers.

During the course of this work, we successfully developed a new method to phase-lock multiple fiber cores in a fiber structure via radiative coupling (not evanescent coupling).

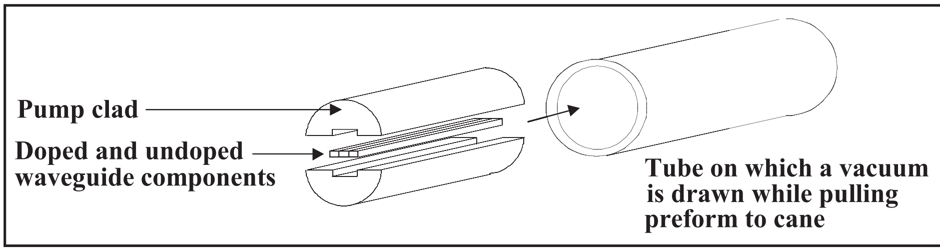

Figure 2. Sketch illustrating the rod-in-tube fabrication technology used to construct the preform for the prototype fiber shown in Figure 1.

This new method, known as antiguiding, which utilizes gain elements radiatively coupled in a "leaky" waveguide array, is analogous to the scheme used earlier for phase locking of laser diode elements. By selective placement of gain regions within a uniform index core, we were able to create a preferred single mode in the fiber. Because the light field is evenly distributed across all cores in this scheme and all gain cores communicate with each other, we anticipate that the scalability of the device will be very favorable.

A cross-sectional view of the prototype Ribbon laser is shown in Figure 1. The waveguide region is rectangular in shape and is comprised of a periodic sequence of gain and no-gain segments having nearly uniform refractive index. It is embedded in a lower-refractive-index cladding region used for diode pumping. Using an end-pumping geometry in which an 808-nm diode array served as the pump source, we were able to run the Ribbon laser predominately in two antiguided modes, as predicted by our modeling.

Figure 2 illustrates the novel "rod-in-tube" fabrication technique that was used to construct the preform for the prototype ribbon fiber. The same technique shows great promise in being able to scale to substantially higher-power-capability fibers.

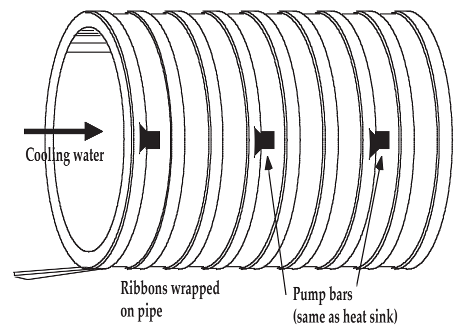

Figure 3. Conceptual design of 30-kW ribbon fiber laser in which a cooled mandrel is used for thermal management, and pump excitation light from diode bars is introduced into the side of the structure.

By using antiguiding mechanism, we successfully demonstrated phase-locking in a five-core Nd-doped glass prototype structure that was fabricated using a novel soft glass fabrication technology. Due to the delocalized nature of their eigenmodes, antiguided structures similar to the ribbon fiber reported here are being evaluated as potential routes to extremely high-power, single-spatial-mode radiation. As an example of a power-scaled system, Figure 3 shows a conceptual design for a 30-kW ribbon fiber. By scaling from 5 cores to 100 cores with fused silica, it should be possible to achieve 30 kW from a single fiber. Achieving this power in laser weapons would be truly revolutionary for the military and, moreover, would have an enormous economic impact in laser material processing and x-ray generation.

—R. Beach, M. Feit, and S. Payne

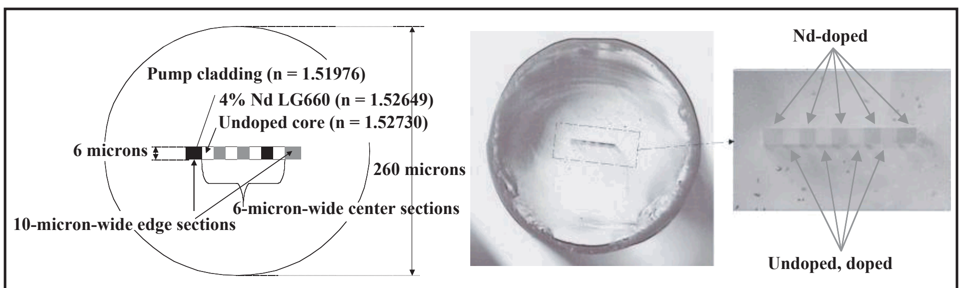

Figure 1. Sketch and photograph of LS&T's prototype five-core Nd fiber in which multiple-gain cores were phased using an antiguiding mechanism.

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